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(19)

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(54) NON-PULSING PUMPING APPARATUS

(71) We, PATERSON CANDY INTERNATIONAL LIMITED, of 21 The Mall, Ealing, London, W5 2PU, a British company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to pumping apparatus in which pumping pulses are eliminated or at least greatly reduced.

Conventional reciprocating pumps reduce their deliveries towards the ends of their strokes and accelerate their deliveries at the commencement of their strokes. The pumping pulses in the delivery induced by these effects can be a nuisance in, for example, dose metering pumps. In consequence, gear or other forms of pump than simple reciprocating pumps are preferred for these applications.

A pulseless pump is known (U.K. Patent 1,300,500), which may be used as a chemical pump. However, although this pump is pulseless for maximum stroke, as the length of stroke is varied pulsing increases, until it is maximum at strokes of minimum length.

An object of the invention is to provide a simule variable stroke pump which can be used for chemical dosing and which is pulseless, or substantially pulseless irrespective of the length of stroke. By "pulseless" is to be included pumps in which either the suction stroke, or the delivery stroke or both strokes are pulseless.

The invention provides pumping apparatus comprising a plurality of identical reciprocating pumps connected in flow paths extending between a fluid inlet and a fluid outlet pump reciprocating means comprising a housing having a pump reciprocating member for each pump extending outwardly through the housing, the housing containing a respective cam follower device for each pump reciprocating member and rotatable cam means for actuating the cam follower device and being shaped to provide a substantially constant aggregate pumping of the pumps, wherein each cam follower device comprises an arm having a convexly-curved surface engaging an at least part circular surface of the respective pump reciprocating member, a lug outwardly offset at one end of the arm and being pivotably mounted on carrier means pivotable about the same axes as the cam means, a cam follower at the other end of the arm engaging the cam means, the pivotal mountings of the lugs on the carrier means being substantially coaxial with the centres of curvature of the said at least part circular surfaces at zero amplitude stroke of the pumps; so that alteration of the stroke amplitude by pivoting still maintains substantially constant aggregate pumping of the pumps over the whole range of stroke.

In one embodiment of the invention there are two pumps and the cam is shaped to provide a substantially constant aggregate suction of the pumps.

Alternatively, the cam is shaped to provide a substantially constant aggregate delivery of the pumps. Such pumping apparatus is particularly simple and can be used as a chemical pump for dosing corrosive chemicals.

The apparatus may, however, have more than two pumps. If three pumps are used, it is possible to arrange them so that the apparatus has a smooth suction rate as well as a smooth delivery rate.

Preferably the cam has a maximum and minimum point of camming lying on an axis of symmetry of the cam, and has six sectors extending equally around the cam, which sectors provide between the minimum and maximum points 60° of constant acceleration, 60° of constant velocity, and 60° of constant deceleration respectively.

Preferably, the pivoting mountings of the lugs on the carrier means are arranged on a circle, and the effective cam surfaces of the arms lie on the circle at maximum discharge of the pumps irrespective of the pivoting of the carrier means, the arms being movable radially inwardly only of the circle.

The invention will now be described in more detail, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of pumping apparatus;

Figure 2 shows a cam profile for producing a constant delivery or a constant suction rate;

Figure 3 shows diagrammatically how full pump evacuation irrespective of length of stroke may be achieved;

Figure 4 shows a cam profile for producing constant delivery and suction rate;

Figure 5 shows a modification of a part of Figure 1 to vary the delivery rate of the apparatus linearly in accordance with the movement of a driven element such as an actuator, and

Figure 6 shows a number of pumps ganged together to be driven by a common drive shaft.

The pumping apparatus of Figure 1 has an inlet 1 which branches into a pair of parallel flow paths 2, 3 which deliver pumped liquid to a common outlet 4.

The flow paths 2, 3 contain respective pumps 5, 6. These are of identical construction and each is provided with a check valve 7 on its inlet side and a non-return valve 8 on its outlet side.

The pump 5 has a piston ram 10 which is reciprocated back and forth to operate the pump. Likewise the pump 6 has an identical piston ram 11.

The lines of action of the rams 10, 11 pass through the axis of rotation of a shaft 12 on which is mounted a cam 13 engaged on opposite sides by two cam followers 14, 15. The cam follower 14 is carried at one end of an arcuate lever arm 16 which is pivoted at its other end 18 and is borne on by a part circular end surface 110 of the ram 10. In similar manner a part circular end surface 111 of the ram 11 bears on the convexly curved outer surface of a second lever arm 17 pivoted at 19 and carrying the cam follower 15. The part circular end surfaces 110, 111 each have a radius of curvature *r* and a centre of curvature 112, 113, respectively. The pivotal points 18 and 19 are only shown diagrammatically in Figure 1 and are in fact outwardly offset as described below with reference to Figure 5.

The pivotal points 18 and 19 are mounted on a carrier 20 which is manually movable through an angle L about the axis of rotation of the shaft 12. As is apparent from Figure 1, the effect of reducing the angle L is to reduce the effective length of the lever arm effective to reciprocate the ram 10, 11 as the corresponding cam follower 14, 15 follows the surface contour of the cam 13. As will be apparent from Figure 5, but is not shown in Figure 1, the centres 112, 113 are substantially coaxial with the offset pivotal points 18, 19 at zero amplitude stroke of the pumps, i.e. when the angle L equals zero. Only if this condition is met can there be pulseless pumping over the whole range of the strokes, including low amplitude strokes.

The carrier 20, the cam 13, and the pivoting arms 16, 17 are contained in a housing 105 into which the rams 10, 11 extend. The housing 105 may contain lubricant which is prevented from escaping around the cams by means of suitable seals (not shown). Thus, the liquid being pumped in flow paths 2 and 3, which liquid may be highly corrosive, is kept separate not only from the lubricant but also from the mechanism inside the housing 105.

The delivery rate of each pump does not vary sinusoidally in phase with the rotation of the cam. The cam 13 is so profiled, that the reduced delivery rate of one pump as it approaches the end of its stroke is compensated by an increased delivery rate of the other pump at the same time.

Figure 2 shows diagrammatically the function of the cam 13 of Figure 1. The cam 13 is divided into four zones A, A′ and V, V′. The zones A, A′ each extend for 90° and move the followers 14, 15 with a constant acceleration. The zones V, V′ extend for 150° and 30° respectively and move the rams 10, 11 with a constant velocity.

Points along the cam in Figure 2 are lettered *a* to *d*, where *a* is at the minimum cam radius (i.e. the commencement of delivery stroke, and *d* is at the maximum cam radius (i.e. the end of delivery stroke), so that the whole delivery stroke extends from *a* to *d via b* and *c*.

During a portion of the delivery stroke of each pump, corresponding to the portion of Figure 2 extending for 150° from *b* to *c*, i.e. constant velocity sector V, the delivery rate of the pump is constant. Between *c* and *d* of the constant acceleration sector A, the delivery rate of one pump falls as it is approaching the end of its stroke at *d*. However, the other pump commences its delivery stroke at the position *a* diametrically opposite the point *c*. Thus the decline in pump delivery of one pump between *c* and *d* is compensated for by the additional delivery of the other pump operating between *a* and *b*.

As the delivery rate of one pump falls to zero at *d* the delivery rate of the other pump increases to maximum at point *b*. In this way the aggregated delivery rate of the pumps is maintained and pulses in the delivery produced by the changing velocity of the pump pistons are eliminated or greatly reduced.

When the pump is in operation the rate of delivery is controlled solely by the speed of rotation of the shaft 12 and the angular position of the carrier 20. If the shaft 12 is rotated at a fixed constant speed, the operating frequency of the pumps is constant and changes in the delivery are obtained by varying the amplitudes of the strokes. This is achieved by moving the carrier 20 manually to different angular positions. The lever arms 16 and 17 have a magnification effect and the stroke length of each pump is dependent on the distance between the pivot point 18, 19 and the associated point of contact of the

ram 10, 11 with the corresponding lever arms 16, 17. If the angle L (Figure 1) is zero, the pivot points 18, 19 lie on the line of action of the rams 10, 11 which therefore remain stationary despite the fact that the cam followers 14, 15 continue to follow the profile of the cam 13.

To obtain maximum delivery from the pumps 10, 11 the angle L is increased until the cam followers 14, 15 lie on the line of action of the rams 10, 11.

In Figure 1, the pivot points 18, 19 lie on a circle 100 shown in broken line. Irrespective of the angular position of the carrier 20 (i.e. the value of the angle L) the "effective" cam surfaces of the lever arms 16, 17 move backwards and forwards across the circle 100 as the cam 13 rotates. By "effective" cam surfaces of the arms 16, 17 is to be understood the line through which the actual camming surfaces of the arms act. This line passes through the centres of curvature 112, 113 and is thus a distance *r* outwardly spaced from the actual camming surfaces of the arms 16, 17. For a minimum pumping stroke, i.e. when L approaches 0, the rams 10, 11 reciprocate substantially at the centre of the reciprocation path in the pumps 5, 6. This means that a dead column of fluid sits in the pumps, and separation of liquids or settlement of particles in this dead column may occur. To avoid this, it is essential that the pumps are almost completely evacuated during each delivery stroke, irrespective of the length of the stroke.

This is achieved, as shown diagrammatically in Figure 3 by ensuring that the effective cam surfaces of the pivot arms 16, 17 always lie on the circle 100 at the end of each delivery. The travel of each follower is indicated by the line EF. The actual size of the cam 13 (not shown in Figure 3) determines the outermost position of the pivoting arms 16, 17. By suitable selection of the cam it is possible to ensure that the effective cam surfaces of the pivoting arms 16, 17 always lie on the circle 100 at maximum stroke. It is then a matter of selecting the length of the rams 10, 11 to ensure that this corresponds to full evacuation of the pumps 5, 6. Partly for geometrical reasons and partly to reduce side thrust on the rams, it is desirable to move the axes of the rams 10, 11 so that they lie on the lines Y_1—Y_1, and Y_2—Y_2 slightly below and above the line YY respectively. In this way the surfaces of contact between the rams and the pivoting arms deviate substantially equally on either side of the normal through the surfaces of contact throughout the stroke, i.e. as the arms move between E and F. The pivot points 18 are movable on rotation of the carrier (not shown in Figure 3), between points C and D for maximum and minimum length of stroke, respectively.

Figure 4 shows a cam 101 which provides constant suction and delivery rates irrespective of the length of the stroke. Three cam followers 102, 103, 104 are arranged at 120° around the cam 101. As can be seen from Figure 4 the cam 101 is symmetrical about its maximum-minimum axis, *a-d* and divided into six equal sectors. Starting from point *a* there is a constant acceleration for 60° to point *b* followed by 60° of constant velocity to point *c*, and then by 60° of constant deceleration to zero velocity at point *d*. Similarly, there is 60° of constant acceleration from *d* to *e*, 60° of constant velocity from *e* to *f* and 60° of constant deceleration from *f* to *a*. At all times; irrespective of ram stroke length, the sum of the forward ram velocities is constant, and the sum of the back ram velocities is constant.

The arrangement shown in Figure 4 can be adapted in a way similar to that shown in Figure 3 to ensure full evacuation of the pumps irrespective of the length of the stroke.

In Figure 5, the parts corresponding to those in Figure 1 are similarly referenced but the reference numerals are primed. Instead of part circular end surfaces, the inner ends of the rams 10′, 11′ are provided with rollers 110′, 111′ having centres of rotation 112′, 113′ with radii *r*′. The arms 16′, 17′ have outwardly offset lugs 118′, 119′ with axes of pivoting 18′, 19′ spaced by a distance R′ from the actual outer cam surface of the arms 16′, 17′. The radius of curvature *r*′ is substantially equal to R′. Thus, at zero amplitude stroke the effective cam surface lies substantially on a circle through the pivots 18′, 19′, or in other words the centres 18′, 19′ are substantially coaxial with the centres 112′, 113′.

The carrier 20′ is rockable about the axis of rotation of the shaft 12 through an angle α. The rocking movement is controlled by a pin 22 attached to the plate 20′ and slidable lengthwise of a slot 23 formed in an enlarged part 24 of a push-rod element 25 capable of displacing axially through a stroke T. The axis of the slot 23 is perpendicular to the line of action of the rams 10′, 11′ so that axial movement of the element 25 produces arcuate movement of the effective lengths of the lever arms 16′, 17′. The length of the pump stroke varies as Sine α, and Sine α is proportional to the stroke length T of the element 25. In consequence the stroke length of the pumps and therefore the delivery rate of the pumping apparatus varies linearly with the movement of the push-rod element 25.

Figure 6 shows an assembly of pump units driven by a common drive shaft 12 from a reduction gear box 30 receiving drive from a motor 31. Units 32 and 33 each comprise a pair of duplex pumps having a con-

troller 34 to enable the delivery rate of the pumps to be altered by angularly moving their respective carriers 20. The pump unit 35 also comprises a duplex pump with a powered stroke change 36 which may take the form of an actuator moving a push-rod 25 as shown in Figure 5.

Various modifications may be made to the above-described pumping apparatus. Thus, the ram pumps may be replaced by diaphragm pumps.

An advantage of the pumping apparatus of the invention is that the fluid or liquid delivered is substantially free of pumping pulses and therefore has a range of advantages such as are numbered in the five examples beneath.

A. Loading Valve

Unless the point of delivery is lower than the top level of the chemical storage vessel no loading valve is required when using the pumping apparatus according to the invention. With loading valves the pumping head is a false one generated by this valve. The entire pump mechanism and drive system must therefore be scaled for the loading valve setting. The absence of such a valve must therefore be an advantage.

B. Mixing

Continuous chemical injection is the ideal in the interest of perfect mixing. Continuous flow improves this and permits the pump stroke speed to run down to low speeds previously considered unwise because of " Slugging " of the dose.

C. Drive Torque

Steady drive torque is at all times desirable and especially so with certain variable speed devices.

D. Flow Checking

Steady flow permits the use of simple flow indicating or detecting devices which cannot be used with conventional pumps.

E. Pump Failure Detection

If a pump drive is running the only form of failure can be gland leakage or valve failure. The former is visible, the latter, difficult to detect in conventional pumps would show up immediately on the proposed design as a flow fluctuation. Steady flow must guarantee correct functioning.

It will be appreciated that the pumps used are conveniently in duplex, and may have a ram or diaphragm head. The heads of the two pumps must of course have identical outputs.

WHAT WE CLAIM IS:—

1. Pumping apparatus comprising a plurality of identical reciprocating pumps connected in flow paths extending between a fluid inlet and a fluid outlet, pump reciprocating means comprising a housing having a pump reciprocating member for each pump extending outwardly through the housing, the housing containing a respective cam follower device for each pump reciprocating member and rotatable cam means for actuating the cam follower device and being shaped to provide a substantially constant aggregate pumping of the pumps, wherein each cam follower device comprises an arm having a convexly-curved surface engaging an at least part circular surface of the respective pump reciprocating member, a lug outwardly offset at one end of the arm and being pivotably mounted on carrier means pivotable about the same axis as the cam means, a cam follower at the other end of the arm engaging the cam means, the pivotal mountings of the lugs on the carrier means being substantially coaxial with the centres of curvature of the said at least part circular surfaces at zero amplitude stroke of the pumps, so that alteration of the stroke amplitude by pivoting still maintains substantially constant aggregate pumping of the pumps over the whole range of stroke.

2. Pumping apparatus as claimed in Claim 1, wherein there are two pumps and the cam means is shaped to provide a substantially constant aggregate suction of the pumps.

3. Pumping apparatus as claimed in Claim 1, wherein there are two pumps and the cam means is shaped to provide a substantially constant aggregate delivery of the pumps.

4. Pumping apparatus as claimed in Claim 1, wherein there are three pumps and the cam means is shaped to provide a substantially constant aggregate delivery and suction of the pumps.

5. Pumping apparatus as claimed in Claim 2 or 3, wherein the cam means comprise a single cam, and the follower devices are arranged diametrically about the cam.

6. Pumping apparatus as claimed in Claim 4, wherein the cam means comprise a single cam, and the cam follower devices are arranged symmetrically around the cam.

7. Pumping apparatus as claimed in Claim 6, wherein the cam has a maximum and minimum point of camming lying on an axis of symmetry of the cam, and has six sectors extending equally around the cam, which sectors provide between the minimum and maximum points 60° of constant acceleration, 60° of constant velocity, and 60° of constant deceleration respectively.

8. Pumping apparatus as claimed in Claim 7, wherein the said pivoting mountings of the lugs on the carrier means are arranged on a circle, and the effective cam surface of the arms lies on the circle at maximum discharge of the pumps irrespective of the pivot-

ing of the carrier means, the arms being movable radially inwardly only of the circle.

9. Pumping apparatus as claimed in any one of the preceding Claims, wherein the carrier means is pivotable by a pin-and-slot mechanism.

10. Pumping apparatus as claimed in Claim 9, wherein the slot of the pin-and-slot mechanism extends perpendicularly to the line of action of at least one of the pump reciprocating members, and the pin is displaced parallel to the line of the pump reciprocating member by a linearly-displaceable member.

11. Pumping apparatus as claimed in any one of the preceding Claims, wherein the said at least part circular surface is formed by a roller rotatably mounted on the inner end of each pump reciprocating member.

12. Pumping apparatus as claimed in any one of the preceding Claims, wherein the pump reciprocating members are rams of the pumps.

MARKS & CLERK.

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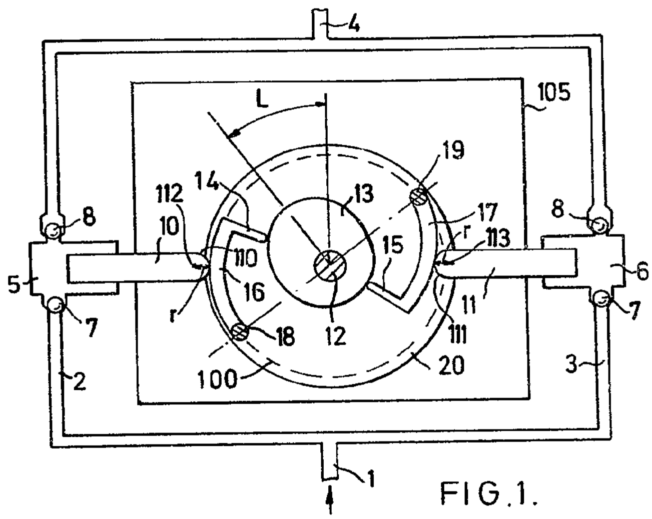
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FIG.1.

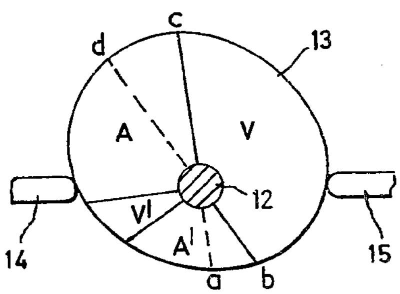
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FIG.2.

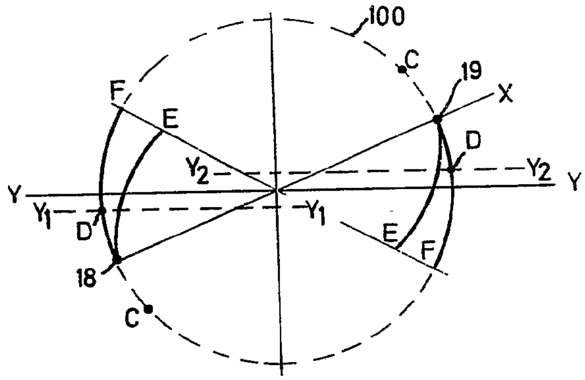

FIG. 3.

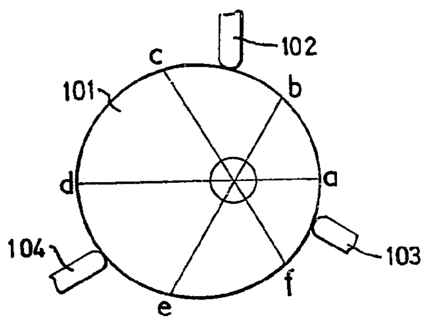

FIG. 4.

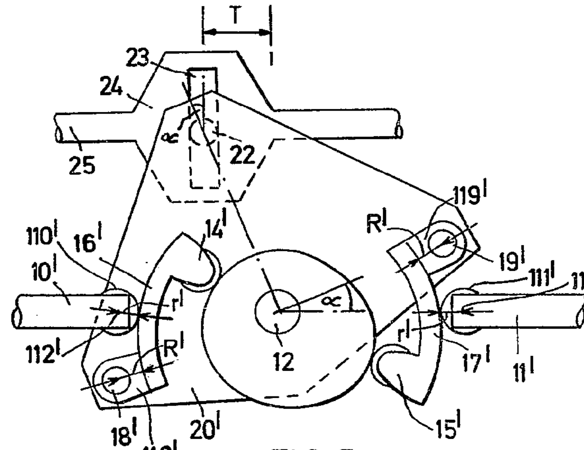
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FIG. 5.

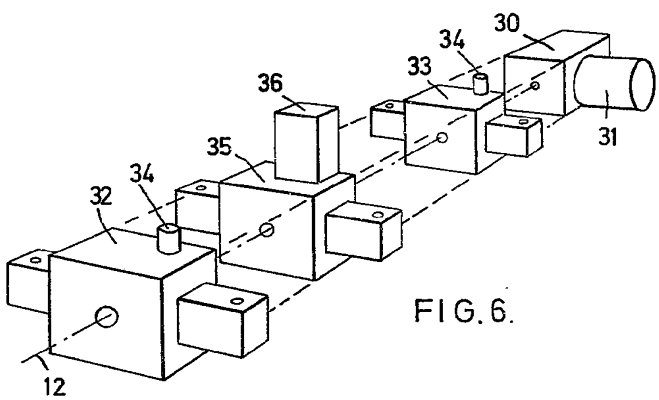
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FIG. 6.